Battery function – more details

We measured $V_m = 1.596$ V when $R_{load} = 10$ Mohm, and $V_m = 1.593$ V when $R_{load} = 100$ ohm.

In general, when the current in the circuit is $I$,

$$V = I (R_{load} + R_{out}), \text{ and}$$

$$V_m = I R_{load}, \text{ and}$$

Applying this in the two situations,

$$V = I_{10M} (10M + R_{out}), \text{ and}$$

$$1.596 = I_{10M} 10M,$$

$$V = I_{100} (100 + R_{out}).$$

$$1.593 = I_{100} 100,$$

From the first set, $V = 1.596*(1+ R_{out}/10M) \sim 1.596V$

From the 2$^{nd}$, $V = 1.593*(1+ R_{out}/100)$

$$1.596*(1+ R_{out}/10M) = 1.593*(1+ R_{out}/100)$$

$$0.003 = R_{out}(1.593/100 – 1.596/10M) \sim R_{out}(1.593/100)$$

$$R_{out} = 0.003*100/1.593 = 0.188 \text{ ohm.}$$

$$V = 1.596 \text{ V}.$$

Given this, when $R_{load} = 33$ ohms, what voltage $V_m$ would you expect?

$$V_m = V R_{load} / (R_{load} + R_{out}) = 1.596*33/(33+0.188) = 1.587 \text{ V, when we observed 1.583 V.}$$

Is this good enough?

This is an example of output impedance (resistance).

If you combine $R_{load}$ vs. $V_m$ data for different values of $R_{load}$, one can fit the results with a function,

$$V_m = V R_{load} / (R_{load} + R_{out}), \text{ where } V \text{ and } R_{out}$$

are optimize the differences between $V_m$ measured and predicted by the equation.
$$V = 1.597 \text{ V and } R_{\text{out}} = 0.3 \text{ ohm.}$$

What happens to a 9-V battery?

$$V = 9.54 \text{ V and } R_{\text{out}} = 10.7 \text{ ohm.}$$

What conclusion(s) would you draw from these results?

**It is useful to represent a real battery with this approximate circuit containing an idealized battery + a resistor.**

The parameter $$R_{\text{out}}$$ tells us one of the major properties of batteries.

What is the cause of this difference in $$R_{\text{out}}$$?

What else are different between large and small batteries?

**More about input/output impedance?**

What would your reaction to the following diagram?

- Complicated?
- How can I understand what goes on inside?
- How can I use it, even if I don’t understand what’s going on inside?

If the circuit can be approximated by

$$V_{\text{out}} = V_{\text{in}} \cdot \text{gain}$$
It would be convenient, wouldn’t it?

Suppose that we can, what can we do with it?

Suppose that a microphone, which produces electronic signal from sound energy, is a battery (albeit AC voltage – ignore the difference between DC and AC for now).

Suppose that the voltage of the idealized battery inside the mic is $V$ and it also has $R_{\text{out}}$.

Suppose that $V$ is fixed once the source level is given, and $R_{\text{out}}$ is the characteristics of the mic (typically 1kohm to 100’s kohm for good Hi-Fi mics)

Connect the above amp to the mic.

In general, what is the voltage, $V_a$, that the amp receives?

What happens if $R_{\text{out}} = 100 \ R_{\text{amp}}$?

Would $V \sim V_a$ (getting the maximum voltage) a good thing to accomplish?

What has to happen if we want $V \sim V_a$?

Or do we want to maximize the power ($P = IV$) that the amp receives?

What has to happen if we were to accomplish this?

What happens if you extract power (energy) from the mic?

Let’s use genecon to see what happen to the ease of turning it when you don’t extract energy from it and when you do.

What do you feel?

If we were to measure the rotation speed of something using this tool, should you extract as much power as possible, or you should try to avoid it?